

# Modelling the effect of stocking rate on the lactation profiles of grazing Holstein - Friesian dairy cows using cubic splines.

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## Introduction

The comparative cost of producing one kg of milk is lower in grazing than in high-energy grain systems due to cheaper production of pastures which account for 70% of the feed base in grazing systems (Kellaway and Porta 1993). However, pasture quality varies greatly between seasons and utilisation still lags behind potential production per hectare (Donaghy, 2004). Whilst increased stocking density enhances better pasture utilisation and improves feed efficiency, stocking rate is a key determinant of pasture utilisation, profitability and productivity per hectare. It has been estimated that every 1tonne increase in DM/ha of pasture utilised will improve return on assets and deliver an extra \$75 M to the State of Tasmania. (Chapman *et al.*, 2004). This is regardless of the level of pasture utilised because the opportunity costs associated with the capital value of land used to grow pasture are constant (Urie, 1995).

Many studies on stocking rate (Bargo *et al.*, 2002; Grainger and Matthews 1989; Holmes, 1996; Penno and Carruthers 1995; Stockdale, 1997), and grain supplementation (McCallum *et al.*, 1995, Kellaway and Porta 1993) in dairy cows have reported milk yield and composition responses at various stages of lactation. On the other hand, only few published studies in pasture-based dairy systems (Horan *et al.*, 2005; Macdonald *et al.*, 2008) have investigated the effect of stocking rates on the shape of the lactation curve over

the entire lactation period. This represents a knowledge gap that our present study intends to fill.

The primary purpose of modeling lactation is to predict the dairy cow's average daily milk yield with minimal error, after adjusting for various environmental factors. While empirical and mechanistic models have been commonly utilised to model the lactation profile of dairy cows (extensively reviewed by Beever *et al.*, 1991), more recently, random regression procedures of legendre polynomials (Kirkpatrick *et al.*, 1994) and cubic splines (White *et al.*, 1999, Silvestre *et al.*, 2006.) are increasingly being used. The objectives of this study were to compare the lactation profiles and performance of dairy cows on dryland versus irrigated pastures at different stocking rates with or without grain supplementation using cubic splines model.

## Materials and Methods

### *Animals and management*

Multiparous dairy cows grazing perennial rye grass (*Lolium perenne*) and white clover under similar pasture management but varying stocking rates and supplementation at the Elliot Dairy Research and Demonstration Station, Somerset, North Western Tasmania were used in three experiments from 1996 to 2002. Thirteen stocking rates ranging from 2.0 to 4.0 cows per hectare (c/ha) were tested. Cows received supplements of hay and/or

concentrate whenever there was feed shortage, except between 1996 and 1998 when some treatments were either supplemented with 500kg of grains per cow per lactation or unsupplemented.

#### *Data size, editing and statistical models*

The data consisted of 12,939 records (572) lactations of mixed parity cows. Editing criteria of the data excluded records without birthdates, calving dates, days in milk less than 5 or greater than 306 or cows with test days lesser than 4, while parities greater than 3 were pooled. Restricted maximum likelihood procedures in ASReml (Gilmour et al. 2002) were utilised to analyse the data using an animal model that fitted days in milk (DIM), stocking rate, year, parity and calving season as fixed effects. Random effects included cow and the splines of DIM nested in stocking rate, year, parity, calving season, while age at calving was used as a covariate. Stepwise regressions of all explanatory variables and their interactions were tested before arriving at a parsimonious model indicated below:

$$y_{ij} = b_0 + b_1 t_{ij} + b_{i0} + b_{i1} t_{ij} + \sum_{k=2}^{q-1} v_k z_k(t_{ij}) + \sum_{k=2}^{q-1} v_{ik} z_k(t_{ij}) + e_{ij}$$

Where  $y_{ij}$  is the  $j^{\text{th}}$  observation on milk yield of animal  $i$  on test day  $t_{ij}$  (DIM),  $j = (5, 305)$ ,

$b_0$  and  $b_1$  are the fixed coefficient and overall linear regression of fixed terms in the model, respectively. Fixed terms in the model include days in milk (DIM), treatment (1, 13), calving season (spring, winter), parity (1, 3) and all their second order interactions.

Non-significant terms were eventually dropped from the final model,

$b_{i0}$  and  $b_{i1}$  are coefficients of the animal and animal x linear effect, respectively, which describe the deviation from the overall regression for animal  $i$

$v$  and  $z$  are the spline and animal x spline terms, respectively, which represent the deviation from the mean spline for animal  $i$ , where  $v_k$  estimates the mean spline-coefficient of animal  $i$  at the  $k^{\text{th}}$  knot point,

$q$  is the number of points (7 in this study),

$z_k(t_{ij})$  is the random spline coefficient for test day  $t_{ij}$ ,

$e_{ij}$  is the random error with mean zero and variance  $\sigma_e^2$ .

## **Results and Discussion**

Cubic splines adequately modelled the bi-weekly milk yield data with low residuals and uncorrelated coefficients which is attributed to the great flexibility of the model (Silvestre et. al., 2006). Without supplementation, mean milk yield did not differ much but was slightly higher in cows grazing at 2.5-3.5 cows/ha stocking rate (SR) compared to cows stocked below at 2.0 c/ha and above at 4.0 c/ha (Figure 1). Irrespective of SR, cows on irrigated pasture had higher peaks except those stocked at 4.0 c/ha (Figure 3). Pasture allocation significantly ( $p < 0.05$ ) increased the rise to peak milk yield in cows stocked at lower stocking rates (2.4-2.5 c/ha) compared to those on 2.8-3.5 c/ha but the later were more persistent and had higher predicted total milk yields (Figure 1).

Table 1: Summary Statistics of treatment effects on mean daily milk yield (L) of Holstein Friesian cows

Treatment	Treatment description	Mean	SD	Minim	Maxim	Count
2.0spare	Control	8.46	3.28	1.83	22.75	5869
2.4dry	Dryland	9.05	3.55	1.84	22.75	252
2.4dryplu	Dryland + grain supplement	10.10	4.04	2.47	20.91	308
2.5dry	Dryland	9.63	3.64	2.31	24.73	1918
2.5dryalt	Dryland alternative species	9.95	3.58	2.42	22.45	832
2.5dryhm	Dryland home agistment*	10.14	3.80	2.09	23.40	1059
2.8Irg30	30% irrigation	9.44	3.94	2.38	22.17	633
2.9dryway	Dryland away agistment	9.77	3.93	2.10	24.35	1160
3.2Irghm	Irrigation home agistment	8.94	3.73	2.09	24.51	1383
3.5Irgway	Irrigation away agistment	9.02	3.69	2.13	23.60	1490
3.4irgplu	Irrigat. + grain supplement	9.08	3.71	2.25	20.61	216
3.4irg	Irrigation	8.72	3.85	1.40	20.49	215
4.0Irg100	100% irrigation	9.47	3.93	2.74	21.66	569

\*Agistment = off-farm grazing

The combined effect of high stocking rate with supplementation resulted in higher production per cow (Figure 1) and per hectare, clearly demonstrating the beneficial effect of boosting the high energy requirements of lactating cows through supplementation. Cows grazing on the highest stocking rate on dryland (2.9 c/ha) produced on average, 3.0 to 4.0 L more milk per day compared with those grazing on the highest stocking rate under irrigation at 4.0 c/ha (Figure 2). In addition, daily initial and peak milk yield (see Figure 3) were higher in cows grazing at 3.2 -3.5 c/ha compared to those grazing on 2.8 and 4.0 c/ha respectively (Figure 3). Macdonald et al., (2008) had reported lower production per cow as stocking rate increased. Average pasture cover (APR) declined rapidly on the irrigated treatments due to the extra feed demand associated with the higher stocking rate resulting in post-grazing residuals of only 1150 - 1250 kg DM/ha, compared to 1500 kg DM/ha on the dryland treatments, thus limiting forage intake and production in the high SR treatment (Sollenberger and Moore, 1997). High SR could potentially affect soil physical and

structural properties, thereby limiting pasture regrowth.

The main positive effects of higher SR and supplementation were evident during mid-late lactation when cows on higher SR showed longer persistency (Figures 1 and 3). Pasture growth rate (kgDM/ha/d) were higher on the irrigated treatments during the summer and autumn months and enhanced longer lactation on the high SR treatments. High SR treatments also improved pasture utilisation, although the carryover effect of the additional pasture produced were minimal because the extra pasture was utilised during the same lactation season. The effect of high stocking rate could not be disentangled from irrigation.

## Conclusions

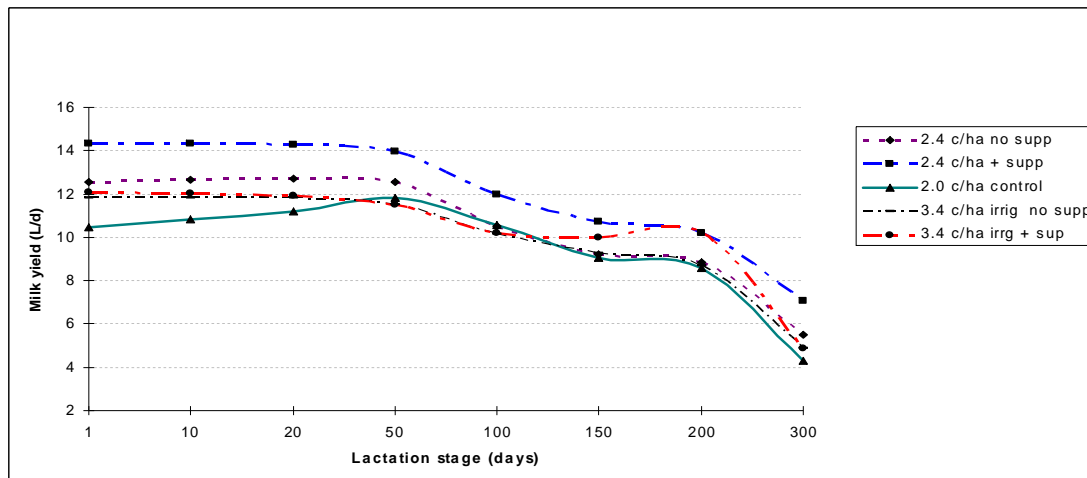
The results demonstrate the accuracy of cubic splines in modelling lactation and that higher stocking rates can improve the efficiency of pasture utilisation when coupled with adequate grain supplementation. Without supplementation the 2.9 c/ha (dryland) and 3.5 c/ha (irrigation) treatments respectively were the best overall but

the 3.4c/ha (irrigation) plus grain supplement was better than both. The poor performance of the 4.0 c/ha treatment highlights the potential of substitution, pasture wastage and the importance of pasture management skills in pasture-based grazing systems. The results confirmed that the key to improving profitability is optimising pasture production and then matching feed demand to feed supply with an appropriate stocking rate, to ensure that both pasture and supplements are utilised efficiently. Other potential lessons and scope for future studies

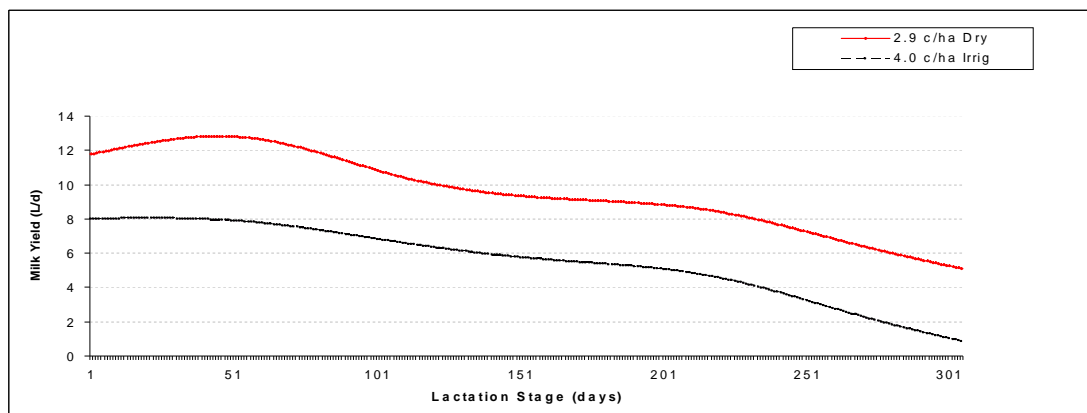
are; to minimise pasture damage in wet conditions and adopting good reproductive management such as earlier calving of dryland herds to take advantage of better pasture growth in the more favourable season depending upon local growth patterns and other management practices.

#### Acknowledgements:

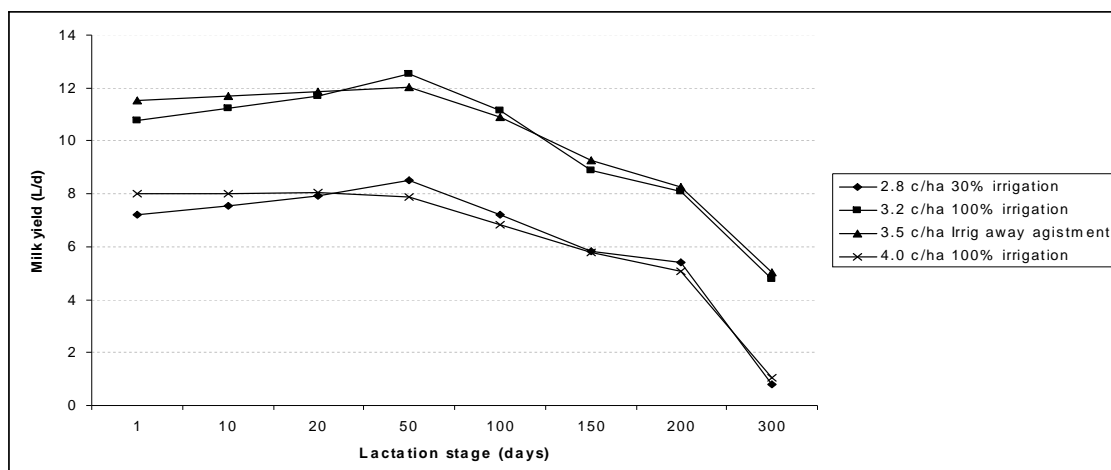
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**Figure 1:** Comparison of Lactation profiles of Friesian dairy cows grazing ryegrass pasture at two stocking rates with or without grain supplementation and control herd.



**Figure 2:** Comparison of the lactation profiles of Holstein-Friesian dairy cows grazing ryegrass at high stocking rates under rain-fed and irrigated conditions



**Figure 3:** Comparison of Lactation profiles of Holstein Friesian dairy cows grazing at different stocking rates on irrigated pastures

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